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NIOSH HEALTH HAZARD EVALUATION REPORT

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AFG Industries
Bridgeport, WV

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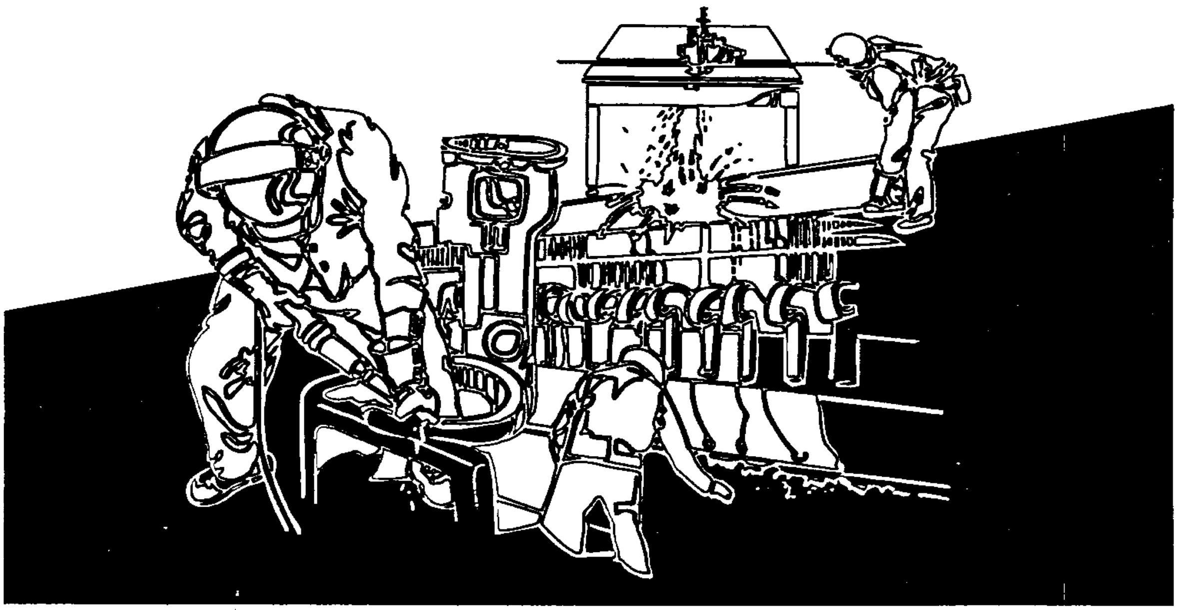

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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Greg Kullman, Hector Ortega, and Jeana Wedgewood of the Field Studies Branch, Division of Respiratory Disease Studies in Morgantown, WV. Field assistance was provided by Tina Gomberg, Hector Ortega, and Greg Kullman. Desktop publishing was performed by Terry Rooney.

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Health Hazard Evaluation Report 97-0265-2781
AFG Industries
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SUMMARY

In July 1997, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation and technical assistance (HHE) from the United Steel Workers of America (USWA) to investigate possible respiratory problems at AFG Industries in Bridgeport, West Virginia. AFG Industries produces sheet glass from raw materials. The respiratory health concerns cited in the request included breathing problems and irritation including nose bleeds; and exposure concerns included adipic acid, crystalline silica, asbestos, sulfur dioxide (SO_2), and nuisance dusts. A walk-through survey was conducted on September 23, 1997. Two industrial hygiene surveys were conducted on May 18 and June 10, 1998. During these surveys, samples were collected for respirable dust and respirable crystalline silica, adipic acid, and SO_2. Medical records were reviewed from 10 workers who complained of work-related respiratory illness. A self-administered questionnaire was mailed to all employees during August and September of 1998. Participants were asked about upper and lower respiratory symptoms, skin and eye symptoms, personal health history, work history, work activities, and tobacco use.

Four personal and two area samples were collected for respirable dust and respirable crystalline silica; all samples were collected from the silo tower area (the hot end of the plant). The respirable dust samples ranged from 0.31 mg/m^3 to 4.86 mg/m^3. The personal crystalline silica concentrations ranged from 0.09 mg/m^3 to 0.35 mg/m^3. The workers assigned to the silo tower used respiratory protection by company policy. The disposable respirators used by workers had an assigned protection factor (APF) of 10 and, when used properly, would reduce exposures ten-fold. Thus, these crystalline silica exposures, if attenuated by proper respirator use, would be below the existing Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PEL), the NIOSH Recommended Exposure Limit (REL), and The American Conference of Governmental Industrial Hygienists (ACGIH), Threshold Limit Exposure Values (TLVs). However, the results from crystalline silica sampling demonstrate the potential for overexposure among workers in the silo tower area if respirators are not used or used improperly.

Fifteen total dust samples were collected for adipic acid in air including 14 personal samples and 1 area sample. Adipic acid was used in the cold end of the plant. The total dust concentrations from this area ranged from 0.25 mg/m^3 to a high of 1.68 mg/m^3. The total adipic acid concentrations ranged from 0.01 mg/m^3 to a high of 0.89 mg/m^3; the mean adipic acid concentration from the total dust samples was 0.10 mg/m^3 with a standard deviation (SD) of 0.22 mg/m^3. The adipic acid content of the airborne total dust samples ranged from 3% to 53% by weight; the mean percent by weight adipic acid concentration in airborne total dust was 13.8% with a SD of 12%. These concentrations were below the existing ACGIH TLV. Sulfur dioxide was not

detected in any of the seven short term area samples taken. Plant management reported that asbestos materials had been removed from the plant and no friable asbestos insulation was observed during this survey.

Of the 312 questionnaires mailed, 144 (46%) were returned; 138 had complete information and were used for the analysis. Results of self-reported respiratory symptoms showed cough in the morning by 42%, phlegm in the morning by 47%, chest tightness by 53%, and wheeze by 52%. Symptoms were also stratified by smoking status and job category; results indicated that lower respiratory symptoms increased among former smokers from the hot end. Overall, work-related health problems were reported in 47% of the workers. These conditions included upper respiratory symptoms by 60%, mucosal irritation by 26%, musculoskeletal by 18%, and hearing loss by 14%. Overall nasal bleeding was reported by 25% (35 of 138) of the workers. Stratification by job category indicated that 30% of cold end workers reported nasal bleeding, as did 23% of the hot end workers, 22% of the warehouse workers, and 7% of maintenance workers. The frequency of nose bleeding was reported 1 to 4 times a year in 74% of the cases. Overall skin irritation was reported in 43% (59 of 138) of the workers. Symptoms by job category indicated that 47% of cold end workers reported skin irritation, as did 69% of the hot end workers, 17% of the warehouse workers, and 36% of maintenance workers. Overall eye irritation was reported by 71% (98 of 138) of the workers. Symptoms by job category indicated that 75% of workers in the cold end reported eye irritation, 69% of the hot end workers, 57% of the warehouse workers, and from 79% of maintenance workers. These findings suggest a high prevalence of mucosal irritation symptoms among plant workers in both cold end and hot end areas.

Thirteen cases of alleged pneumoconiosis were identified in the OSHA 200 logs; this prompted a review of the medical records. Ten medical records were obtained. Of these, the average age was 42 years. The tenure in the glass industry was 21 years. Radiographic evaluations conducted by certified B Readers from a medical group contracted by the company as well as NIOSH's B Reader physician did not document any finding related with occupational pneumoconiosis.

A review of AFG's OSHA 200 log from 1996 included 63 cases of musculoskeletal injuries, seven cases of alleged pneumoconiosis, three cases of hearing loss, and two eye related injuries. During the first nine months of 1997, 41 cases of musculoskeletal injuries, one case of eye injury, and one case of SO_2 inhalation were reported.

These results from crystalline silica sampling from the silo tower area demonstrates the potential for overexposure among AFG workers; overexposure risks would be attributable to no respirator use or improper use in the silo tower area. Worker exposures to adipic acid did not exceed existing exposure limits recommended by the ACGIH or enforced by OSHA. Workers in general had a high prevalence of irritative symptoms including nasal bleeding, skin irritation, and eye irritation. Recommendations for reducing exposures and irritant symptoms are provided in this report.

Keywords: SIC Code 3211, glass manufacturing, adipic acid, crystalline silica, sulfur dioxide, respiratory irritants

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INTRODUCTION

In July 1997, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the United Steel Workers of America (USWA) to investigate possible respiratory problems at AFG Industries in Bridgeport, West Virginia. AFG Industries produces sheet glass from raw materials using a float process. The HHE request cited exposure concerns including adipic acid, crystalline silica, asbestos, sulfur dioxide (SO_2), and nuisance dusts. The respiratory health concerns cited in the request included breathing problems and irritation, including nose bleeds.

A walk-through survey was conducted at AFG Industries on September 23, 1997. Two industrial hygiene surveys were conducted at the site on May 18 and June 10, 1998. Medical records were reviewed from 10 workers who complained of work-related respiratory illness. In August 1998, a self-administered medical questionnaire was mailed to each company employee. In November 1998, after receiving the industrial hygiene analytical results from the laboratory, both labor and management were informed of the crystalline silica sampling results by telephone. This final report summarizes the environmental and medical investigations and closes this evaluation.

BACKGROUND

The AFG Industries Inc. plant in Bridgeport, WV is one of the nation's leading producers of flat, clear glass producing on average 560,000 tons of glass per day with a plant capacity of 625,000 tons per day. The plant has been in operation since 1976. At the time of this investigation, the plant employed approximately 360 workers; plant operations were 7 days per week, 3 shifts per day.

The raw materials used for glass manufacturing were received by rail and truck. Materials were received, stored, and mixed in a large tower silo. At the time of our investigation, the basic ingredients used for glass manufacturing included silica sand (60%), soda (19%), calcium (5%), salt cake (6%), dolomite (15%), carbon (<1%), and rogue (<1%). Recycled glass was also used as an ingredient. After mixing, the ingredients are transported by conveyor belt to the furnace located in the hot end of the plant.

In the hot end of the plant, the raw materials are conveyed into the furnace and heated to a temperature of approximately 2900 degrees Fahrenheit (°F). The furnace is operated with a natural gas fuel source. The raw materials are melted to form the glass. From this point, the glass is conveyed in a long sheet through the various hot end processes designed to produce flat glass of the specified physical properties. After formation, the glass is conveyed into a tin float bath and through roll machines to control the glass width and thickness. SO_2 is applied near the end of the float tin bath as a lubricant to prevent scratching of the glass by the rollers. The annealing process follows, where a controlled cooling temperature is used to obtain the desired glass thickness and physical properties.

The cold end production processes include cutting, packing, and closing of the glass product. Just prior to the cutting process, a 2% solution of adipic acid in water is applied to the glass to prevent staining. Next the glass is scored and broken to desired specifications; this cutting process occurs as a part of automated, line operations. Several glass cutting steps may be required to obtain the desired size specifications. After cutting, the glass is conveyed to the packing operations. Larger pieces of glass are packaged on the main packing line while smaller pieces of glass are sent to a spurs packing line. During packing, workers remove the cut glass from the line by hand and stack it on metal / wooden pallets. Prior to packing, the glass is automatically dusted with a solid white powder called Lucor®. The Lucor® also contains adipic acid and is applied to the glass for packing as an interdigitizing agent to prevent the glass from adhering and being scratched. The Lucor® is applied automatically by machine just prior to hand removal from the line and hand packaging. After packing, pallets of glass are transported by a fork lift to an adjacent area where plastic stretch wrap is applied to the glass pallets to secure the glass for transport. Next, the pallets of glass are transported to a large warehouse area for storage prior to distribution to market.

METHODS

Industrial Hygiene Evaluation

Industrial hygiene air samples were collected from the AFG Industries Plant in Bridgeport, WV, on May 18 and June 10, 1998. Samples were collected for several environmental analytes including crystalline silica, adipic acid, and SO_2. Asbestos containing materials were no longer used in the plant. During each industrial hygiene survey, personal and area air samples were taken to determine the concentrations of crystalline silica and adipic acid (in solid, powder form). Area samples were also collected to measure concentrations of SO_2. Personal samples were taken to determine worker exposures while area samples were taken to determine the general, area concentrations to aid estimates of worker exposure. The sampling and analytical methods used for this HHE are summarized in Table 1.

Crystalline silica samples were taken only in the tower silo where silica sand and other glass manufacturing materials were received, stored, and mixed. Adipic acid samples were collected from the cold end manufacturing operations proximate to the main and spurs packing operations where Lucor® was applied. Concentrations of SO_2 were measured at two gas cylinder storage areas and in a furnace application area.

Medical Evaluation

Review of Medical records: Medical records were reviewed from ten workers who complained of work-related respiratory illness.

Questionnaire: A self-administered questionnaire was mailed during August and September 1998. The questionnaire was sent to all employees identified in a list of workers provided by the USWA. Participants were asked about upper and lower respiratory symptoms, skin and eye symptoms, personal health history, work history, work activities, and tobacco use.

Job Categories: In order to facilitate the analysis, workers were classified into one the following jobs: hot end, cold end, warehouse, and maintenance.

Data Analysis: Descriptive statistics and tables were produced with JMP Start® Statistics version 3.2.1, SAS Institute Inc. Tables were also generated using Excel spreadsheets. Differences were considered significant at a level of $p < 0.05$.

RESULTS

Industrial Hygiene Results

Respirable Dust and Crystalline Silica

Table 2 presents the respirable dust and crystalline silica sampling results from both personal and area samples. The table contains the following variables for each sample: the sample number, the job or area, the sampling date, the sample air volume, the respirable dust concentration, and the crystalline silica concentration. Concentrations are presented in milligrams of dust or crystalline silica per cubic meter of air (mg/m^3). Four personal and two area samples were collected during two days of sampling; all samples were collected from the silo tower area. The respirable dust samples ranged from 0.31 mg/m^3 to 4.86 mg/m^3. The area respirable dust concentrations were higher than the personal sample concentrations. The crystalline silica sample concentrations (area and personal) ranged from 0.09 mg/m^3 to 0.89 mg/m^3. The area crystalline silica concentrations were higher than personal concentrations. The two workers assigned to the silo tower (dry batch unloader and cullit truck driver) were required to use respiratory protection. The NIOSH approved disposable respirators used by these workers would reduce exposures ten-fold when used properly. Statistical results for the six respirable dust and crystalline silica samples are presented in Table 3.

Adipic Acid

Table 4 presents the total dust and total adipic acid sampling results from fifteen filter cassette samples collected from the cold end packing and closing operations. The table presents the sample number, the job or area sampled, the sampling date, the sample air volume, the total dust concentration, and the adipic acid concentration. Concentrations are presented in milligrams per cubic meter of air (mg/m^3). Fifteen samples were collected including 14 personal samples and 1 area sample. Table 5 provides statistical results for the total dust and adipic acid samples. The total dust concentrations ranged from 0.25 mg/m^3 to a high of 1.68 mg/m^3; the mean total dust concentration was 0.50 mg/m^3 with a SD of 0.35 mg/m^3. The total adipic acid concentrations ranged from 0.01 mg/m^3 to a high of 0.89 mg/m^3; the mean adipic acid concentration from the total dust samples was 0.10 mg/m^3 with a SD of 0.22 mg/m^3. The adipic acid content of the airborne total dust samples ranged from 3% to 53% by weight; the mean percent by weight adipic acid concentration in airborne total dust was 13.8 % with a SD of 12%. (Note: See environmental evaluation criteria in Appendix 1).

Table 6 presents results for total dust and adipic acid samples collected using a two-stage cascade impactor; this sampler provides capability to resolve the size characteristics of the airborne particulate. Listed in Table 6 are the sample number, job, date, air volume sampled, total dust concentration, adipic acid concentration, and the percent mass of adipic acid. Results are presented in mg/m^3 for each stage of the cascade impactor sample (stages 1, 2, and Final) and for the total sample (Total). Six samples were collected from the cold end packing and closing operations. The airborne total dust concentrations collected using the cascade impactor sampling methods ranged from 0.29 mg/m^3 to 2.11 mg/m^3; the mean total dust concentration was 0.66 mg/m^3 with a SD of 0.71 mg/m^3. The airborne adipic acid concentrations ranged from 0.02 mg/m^3 to a high of 0.08 mg/m^3; the mean adipic acid concentration was 0.05 mg/m^3 with a SD of 0.02 mg/m^3. Most of the airborne adipic acid particulate in these impactor samples (53%) were collected of the first stage of the impactor sample; this stage has a median aerodynamic cut point of approximately 10 micrometers. Approximately 40% of the airborne adipic acid was collected on the second stage of the impactor. This stage collects particulate with a smaller aerodynamic size; it has a median aerodynamic cut point of approximately 3.5 micrometers. The remaining 16% of adipic acid was in the smallest size category and retained on the impactor's back-up filter. Table 5 presents summary statistics for the total dust and adipic acid samples collected by both filter cassette and impactor sampling methods.

Other Contaminants

Sulfur dioxide was not detected in any of the seven short term area samples taken.

Plant management reported that all asbestos had been removed from the plant. No friable asbestos insulation materials were observed and no asbestos samples were taken.

Medical Results

Of the 312 questionnaires mailed in August 1998, 144 (46%) were completed. Of these, six were removed from the analysis because insufficient data. Results are presented as a percent; several questions of the survey were not completed and the actual numbers are indicated in parenthesis. Among the participants who completed the questionnaire 94% (130/138) were males, the mean age was 44 years (range 22-62).

Respiratory Symptoms

Respiratory symptoms included cough in the morning in 42% (58 of 138), phlegm in the morning in 47% (65 of 138), chest tightness in 53% (72 of 138), and wheeze in 52% (71 of 138). Wheeze and phlegm and in the morning were increased among hot end workers (Table 7). The percent of symptoms stratified by smoking status is presented in Table 8. Further analysis by smoking status and job category indicated that wheeze, cough, and phlegm in the morning were increased among former smokers from the hot end (Table 9). The percent of workers at the hot end that never smoked was relatively low (23%) in contrast to cold end workers (48%). These observations are limited due to the small number of workers in most of the job categories. In addition, workers reported nasal obstruction or postnasal drip in 80% (110 of 138). These symptoms were predominantly associated with dust at work in 51% (56 of 110). Nasal symptoms improved while away from work in 62% (69 of 112) of the participants.

Past-medical History

Medical conditions such as bronchitis, sinusitis, hay fever, or asthma were similarly distributed among all job categories. Previous diagnosis of bronchitis was reported in 29% (35 of 119), sinusitis in 37% (46 of 124), hay fever in 26% (30 of 117), and asthma in 10% (11 of 111).

Other Symptoms at Work

Five percent (6 of 130) of the workers had changed their job due to work-related health problems. Of these, three employees worked in the cold end area, two in the hot end area, and one in the warehouse. Overall, work-related health problems were reported in 47% (59 of 126) of the workers. These conditions included: 60% upper respiratory symptoms, 26% mucosal irritation, 18% musculoskeletal problems, and 14% hearing loss. Six workers reported a health condition that was not work-related.

Mucosal and Skin Irritation

Nasal bleeding was reported in 25% (35 of 138) of the workers. Nasal bleeding stratified by job category was reported in 30% of the cold end workers, 23% of the hot end workers, 22% of the warehouse workers, and 7% of maintenance workers (Table 10). Fifty percent of the cases did not identify a specific pattern, 11% reported onset symptoms after the start work, 11% between one to three hours, and 7% between four to eight hours. The frequency of nose bleeding was reported one to four times a year in 74% of the cases.

Eye irritation was reported in 71% (98 of 138) of the workers. Eye irritation stratified by job category was reported in 75% of the cold end workers, 69% of the hot end workers, 57% of the warehouse workers, and 79% of maintenance workers (Table 10). Forty-two percent of the symptoms were present from 7 to 30 days, and more than 30 days in 33% of the cases. Eye symptoms improved while away from work in 68% (69 of 102) of the cases.

Skin irritation was reported in 43% (59 of 138) of the workers. Skin irritation stratified by job category was reported in 47% of the cold end workers, 69% of the hot end workers, 17% of the warehouse workers, and 36% of maintenance workers (Table 10). Duration of symptoms ranged from one day to more than one month. The frequency of these symptoms was between one to two days in 61% of the workers, from three to 30 days in 17%, and more than 30 days in 22%.

Review of Medical Records

Fifteen cases of occupational pneumoconiosis were identified in the OSHA 200 logs. Of these, 4 were reported in 1995 and 6 in 1996. The average age of this group of workers was 42 years (range 35-59); the average tenure was 21 years. These cases of pneumoconiosis were in litigation at the time of this investigation. Individuals worked in different job categories during this period of time. Smoking history was available in only four workers with a median time of 11 years. The symptoms reported were cough, shortness of breath, and wheeze. The average duration of these respiratory symptoms was 6 years. Medical tests used to evaluate these conditions included pulmonary function testing. Nine workers were within normal limits for FVC (forced vital capacity) and FEV_1 (forced expiratory volume at one second) (> 80% predicted). Only one worker had lower FEV_1 with minimal airway obstruction. Radiographic reports were re-evaluated by examination of chest x-rays according to the 1980 International Labour Office (ILO) system by a NIOSH-certified B Reader [a B Reader is a physician who has demonstrated the ability to classify chest x-rays for the pneumoconiosis (dust diseases of the lung)]. The findings were not related with occupational pneumoconiosis.

OSHA 200 Log

During 1995, AFG's OSHA 200 log included 77 musculoskeletal injuries (mostly sprains and lacerations), 8 cases of pneumoconiosis, 5 eye related injuries (foreign body), and 3 cases of hearing loss. In 1996, 63 cases of musculoskeletal injuries, 7 cases of pneumoconiosis, 3 cases of hearing loss, and 2 eye related injuries (foreign body) were reported. During the first nine months of 1997, 41 cases of musculoskeletal injuries, one case of eye injury, and one case of SO_2 inhalation were reported.

DISCUSSION

Workers involved in the manufacturing of glass are exposed to a several different occupational health and safety hazards.[5] The occupational exposure concerns cited in this health hazard evaluation request included sulfur dioxide, asbestos, crystalline silica, and adipic acid; the health symptoms reported in this request included breathing problems and nose bleeding. Both industrial hygiene and medical assessments were completed to address these occupational exposures and health concerns at the AFG Industries plant in Clarksburg, WV. Asbestos materials are no longer used in the plant according to plant management. During the environmental surveys, insulation materials resembling asbestos were not observed in any of the plant areas visited.

Sulfur dioxide is a common agent in glass manufacturing and the potential for worker exposures exists through both the application and storage activities. SO_2 is a strong irritant to skin and mucus membranes including the upper respiratory tract. Some of the plant workers reported the occasional presence of irritating odors in the proximity of the sulfur dioxide storage and application areas. Sulfur dioxide exposures have been an issue at this AFG Plant in the past as evidenced by the previous NIOSH HHE project in 1993 as well as an incident reported in the OSHA 200 Log for 1997. However, during our surveys, none of the samples for sulfur dioxide were above detectable limits, (approximately 0.5 ppm). These samples were collected during both industrial hygiene surveys from storage and application areas. The NIOSH REL for SO_2 is 2 ppm as a TWA and 5 ppm as an exposure ceiling (C).[1]

Crystalline Silica is recognized as an exposure hazard in the glass making industry.[5] Overexposures to crystalline silica can cause a form of pneumoconiosis called silicosis. Silicosis results from inhalation of crystalline silica, which exists in nature in various forms (e.g. alpha quartz, cristobalite, tridymite). The classic type of pneumoconiosis (silicosis) develops in individuals who experience moderate exposure over many years, usually 10 to 20. Less common forms of silicosis may develop with more intense short exposures, reduced particle size, or altered host response. Crystalline silica is also recognized to be a potential human carcinogen.[6] Current dust exposure limits exist to provide protection from classical silicosis. The limits of respirable silica that provide safety from an excess risk of bronchogenic carcinoma, particularly in smokers, are not known. Thus, smoking cessation and prevention should be encouraged in workplaces with silica exposure.

The results of the crystalline silica sampling show the potential for overexposure among workers in the silo tower area. The four personal samples collected from the two workers in this area (batch unloader and cullet truck driver) ranged from 0.09 mg/m^3 to a high of 0.35 mg/m^3 of crystalline silica (alpha-quartz). The two area samples collected from this location had higher concentrations than the personal samples. The NIOSH REL for crystalline silica is 0.05 mg/m^3 as a TWA.[1] The ACGIH® TLV for crystalline silica as alpha-quartz is 0.1 mg/m^3 also as a TWA.[2] The OSHA PEL for crystalline silica is based on the following formula: 10 mg/m^3/(% SiO_2 + 2); this PEL is for TWA exposures.[3] (Note: both labor and management were informed of these sampling results by telephone once they were received from the laboratory). Worker exposures to crystalline silica at AFG Industries were attenuated below these exposure limits by the use of respiratory protection. NIOSH approved disposable respirators with an assigned protection factor (APF) of 10 were used by workers during sampling. Workers in the silo tower area were required by plant management to wear respiratory protection when working in these areas. However, these sampling results suggest that the potential for crystalline silica overexposure exists when respirators are not used or when used improperly. Consequently, a reduction of airborne contaminants by engineering controls is recommended rather than the use of respiratory protection. Respirators should be used as a secondary means of exposure control for crystalline silica in the silo tower area. The plant has an existing respiratory protection program with respirator fit testing. Additionally, following the reporting of these sampling results, the plant fit-tested and supplied workers in the silo tower area with one-half face-piece, air purifying respirators.

Adipic acid is an aliphatic, carboxylic acid; its physical form is that of a solid, white powder. Adipic acid has a variety of industrial uses including the manufacturer of nylon fibers, esters, and in plasticizers. It is also a food additive.[7-9] Adipic acid was used predominantly in the cold end operations at AFG Industries. It was applied to the glass as a 2 % liquid mixture near the bridge operator's station. The majority of the adipic acid used at AFG Industries was in the product called Lucor®, an interdigitizing or interleaving agent for glass packaging, storage, and transport. This product is used in solid, powder form to prevent glass panels from adhering and scratching during storage and transport. Lucor® is a mixture of adipic acid (approximately 50% by weight) and Lucite® beads - a methyl methacrylate polymer (50% by weight). The product Lucor® was used at AFG Industries in the cold process areas. Workers in these areas were exposed to this material and adipic acid as it was applied to the glass, during glass handling / packaging, and by aerosolization of accumulated powder observed on floors and surfaces near areas of application.

The industrial hygiene sampling results indicated that airborne total dust concentrations in the cold end glass handling operations ranged from 0.02 to 1.68 mg/m^3 with a mean concentration of 0.5 mg/m^3 from the filter cassette samples. Adipic acid was present in these airborne dusts, on average, at approximately 14% by weight. The adipic acid concentrations in air ranged from approximately 0.01 to 0.89 mg/m^3 with a mean adipic acid concentration of 0.1 mg/m^3 (filter cassette samples). Most of the airborne adipic acid particulate (53%) was in an aerodynamic size range with a median aerodynamic diameter of approximately 10 micrometers suggesting deposition in the upper airways. None of these adipic acid exposures measured at AFG Industries exceeded the ACGIH TLV of 5 mg/m^3 as a TWA or the OSHA PEL for Particulates Not Otherwise Regulated (PNOR), also 5 mg/m^3. However, this limit may not be entirely appropriate as PNORs are defined as relatively nontoxic. Worker exposures to the Lucor® and adipic acid from the cold end packing lines were observed to occur as a result of: 1) materials application, 2) reaerosolization of settled particulate, and 3) by the manual removal of glass sheets from the line and stacking onto pallets. Some workers described worse- case exposure conditions, referred to as *Snow on the Mountain*, when extra Lucor (adipic acid) was applied to the glass to prevent scratching per manufacturer's request. Respiratory protection was not routinely used by the workers in this area. Floor fans were used in the packing area but they were not optimally positioned to direct aerosolized dust away from the packing workers. A local exhaust system with a bag house filter collector was being installed on the main line packing operations to control dust and adipic acid exposures; however, this system was not operational at the time of our survey. This system, when operable, should help reduce worker exposures on the main line packing operations by controlling adipic acid release during application and also the reintrainment of settled particulate.

An excess of respiratory symptoms in workers exposed to low molecular weight irritant fumes has been reported in several industries. In particular, exposure to irritants in the silicon carbide, synthetic fibre, and dye industries has been associated with an increase in cough, phlegm, wheeze and dyspnea among workers.[10-12] Although, few studies have been reported in the glass industry, the related symptoms included chest pain, dyspnea, cough, and wheeze.[13] A report in a glass industry in the U.K. showed a significant excess of upper and lower respiratory symptoms (except wheeze) in a randomly selected group of workers compared to matched controls.[14] More recently, a cohort study of 69 bottle glass manufacture workers demonstrated work-related eye, nose, and throat irritation in 74% of the workers. Other symptoms included cough in 66% and shortness of breath in 64% of the exposed workers. There was no difference seen in the pattern or frequency of symptoms between hot and cold end workers.[15] NIOSH conducted an investigation in a glass industry several years ago,[16] where Lucor® (adipic acid) was used. Among the exposed workers, 46% (6 of 13) complained of eye and throat irritation and 23% (3 of 13) of skin irritation. Results of personal breathing zone and general air sampling for adipic acid showed levels below the analytical limit of detection.[16] The results of this HHE show worker symptoms similar to other reports from the glass industry. In particular the findings of increased mucosal and skin irritation and lower respiratory symptoms.

CONCLUSIONS

Worker exposures to SO_2 were below detectable levels during this HHE survey; however, SO_2 exposure incidents are reported on the OSHA 200 Log and described by workers suggesting the potential for periodic exposure problems. Employees in the silo tower area (batch unloader and cullet truck driver) work in an environment with high concentrations of crystalline silica in air as demonstrated by sampling results from this survey. Attenuation of crystalline silica exposures to acceptable levels was primarily dependent on the use of respirators as required by company policy. These sampling results suggest that the potential for crystalline silica overexposure exists when respirators are not used or when used improperly for work in the silo tower area. Adipic acid concentrations were present at quantifiable levels in air samples from in the cold end of the plant; however, worker exposures were below the existing ACGIH TLV for adipic acid and the OSHA PEL (for PNOR). Former smokers from the hot end area reported increase wheeze and productive cough. This observation might be affected by the small number of participants in this survey. Plant workers report a high prevalence of irritative symptons including nasal bleeding, skin and eye irritations in relation to other non-exposed workers.[14]

RECOMMENDATIONS

1. When feasible, a reduction of airborne contaminants by engineering controls is recommended versus the use of respiratory protection. Respirators should be used as a secondary means of exposure control for crystalline silica in the silo tower area. The installation of additional engineering controls is recommended in the silo tower area to reduce the crystalline silica concentrations in air and the potential for worker overexposures. This could include better enclosure and exhaust ventilation at material mixing and transfer points in the silo

tower. Respirators should be used for intermittent, high exposure tasks (such as clean-up activities, work in the pit, etc.) and during the improvement of existing engineering controls. Respirators should be used as a part of a formal respiratory protection program. Periodic resampling for crystalline silica should be done to ensure that workers in the silo tower area are not overexposed.

2. Both pre-placement and annual medical examinations for workers in the silo, exposed to crystalline silica, should include:

   a) A medical symptoms and occupational history to collect data on worker exposure to crystalline silica dust are recommended. This information should be collected from an employee by the health care professional conducting the examination.

   b) Annual chest x-ray (posterior-anterior 14" x 17"), preferably obtained using a high kilo-voltage technique, and classified by a B Reader according to the 1980 International Labour Organization (ILO) International Classification of Radiographs of Pneumoconioses. This is a primary part of the respiratory protection program currently established.

   c) Annual pulmonary function tests, including forced vital capacity (FVC) and forced expiratory volume at one second (FEV_1), using equipment and methods consistent with the American Thoracic Society (ATS) recommendations. Again this is a primary part of the respiratory protection program currently established.

3. Further reduction in worker exposures to Lucor® / adipic acid is recommended in the cold end packing areas to help reduce irritative symptoms experienced by workers in these areas. The installation and operation of the local exhaust ventilation system should help control adipic acid concentrations in the cold end, main line operation. (This system was nearing completion at the time of our surveys and should be operational). Other recommended controls include:

   a) Where possible, consider product substitution to interdigitizing agents a lower content of adipic acid or other irritating agents.

   b) Use the minimum amount of Lucor® / adipic acid possible to achieve good packing operations. If increased amounts are occasionally required (i.e., *Snow on the Mountain*), alert workers to this situation and make available additional personal protective equipment (eye, skin, and respiratory protection).

   c) Improve plant housekeeping to prevent the accumulation of Lucor® / adipic acid on plant floors and other surfaces to control exposures from the aerosolization of settled particulate.

   d) Use the existing floor fans to better direct the air flow / adipic acid away from the workers during packing operations.

   e) Periodically sample workers in the cold end packing operations to evaluate adipic acid exposures and the effectiveness of exposure control methods.

   If these control options are not sufficient to reduce adipic acid concentrations to a level which controls worker irritative symptoms, additional engineering controls should be added to the packing lines to reduce exposures.

4. Medical Screening: A medical monitoring program should be in place for the early detection and prevention of acute and chronic work-related adverse health effects. This may include complete physical examination with particular attention to the respiratory system. Workers with clinical evidence of mucosal irritation symptoms should receive a more thorough medical evaluation and targeted exposure control efforts.

5. Smoking should be prohibited inside the facility, it should be only be allowed outside or in designated areas with dependent exhaust ventilation such that smoke is not re-circulated within the building. Employees who continue to smoke should be counseled on how smoking may exacerbate the adverse health effects of occupational respiratory hazards.

6. Promptly respond to and correct any SO_2 releases to prevent worker overexposures.

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Table 1. Air Sampling and Analytical Methods
HHE 97-0265, AFG Industries, Bridgeport, West Virginia

Substance	Sampling Media	Flow Rate (lpm)	Analytical Method
Respirable Dust and Respirable Crystalline Silica	10 mm nylon cyclone with PVC filters	1.7	1. Gravimetric analysis by NIOSH Analytical Method (NAM) 0500 (4th edition) 2. Crystalline silica by NAM 7500
Airborne Dust and Adipic Acid	Two-stage cascade impactor with teflon impactor substrates	2.0	1. Gravimetric analysis by NAM 0500 (4th edition) 2. Adipic Acid by HPLC
Total Dust and Adipic Acid	37 mm teflon filters in a closed-face filter cassette	2.0	1. Gravimetric analysis by NAM 0500 (4th edition) 2. Adipic Acid by HPLC
Sulfur Dioxide	Short term, colormetric indicator tubes	--	Direct reading - concentration determined by colormetric indicators on the indicator tube

HPLC - High Performance Liquid Chromatography, PVC - Polyvinyl Chloride, mm - millimeter.

Table 2. Respirable Dust and Crystalline Silica Sampling Results
HHE 97-0265, AFG Industries, Bridgeport, West Virginia

Sample Number	Job/ Area	Sample Date	Volume (m^3)	Respirable Dust (mg/m^3)	Crystalline Silica (mg/m^3)
98-633	Dry Batch Unloader	6/10/98	0.70	0.47	0.22
98-836	Dry Batch Unloader	5/18/98	0.71	1.30	0.35
98-629	Cullit Truck Driver	6/10/98	0.72	0.31	0.17
98-621	Cullit Truck Driver	5/18/98	0.72	4.86	0.09
98-638	Area - Outside Silo	6/10/98	0.71	1.30	0.89
98-645	Area -Outside Silo	5/18/98	0.70	1.53	0.68

Table 3. Summary Sampling Results for Respirable Dust and Crystalline Silica
HHE 97-0265, AFG Industries, Bridgeport, West Virginia

Substance	Sample Size	Mean (mg/m^3)	SD (mg/m^3)	Range
Respirable Dust (Area & Personal)	6	1.63	1.66	0.31 to 4.86
Crystalline Silica (Area & Personal)	6	0.40	0.32	0.09 to 0.89

Table 4. Total Dust and Adipic Acid Sampling Results
HHE 97-0265, AFG Industries, Bridgeport, West Virginia

Sample Number	Job / Area	Sample Date	Volume (m^3)	Total Dust Concentration (mg/m^3)	Adipic Acid Concentration (mg/m^3)	% Adipic Acid[2]
223	Packer- ML[1]	6/10/98	0.79	0.32	0.03	9.4
224	Packer- SL[1]	5/18/98	0.79	0.57	0.14	26
225	Packer- ML[1]	5/18/98	0.77	0.64	0.04	6.2
226	Packer ML[1] & SL[1]	5/18/98	0.81	0.44	0.05	11
227	Back-up Bridge Operator	6/10/98	0.76	0.25	0.04	16
228	Packer-ML[1]	5/18/98	0.78	0.28	0.02	7.1
229	Clean-up - ML[1]	5/18/98	0.76	0.56	0.04	7.1
230	Packer- SL[1]	6/10/98	0.73	0.60	0.07	12
231	Lift Operator	6/10/98	0.76	0.28	0.03	11
232	Bridge Back-up Operator	5/18/98	0.83	0.41	0.06	15
235	Packing: Bridge Utility	5/18/98	0.79	1.68	0.89	53
237	Closer	6/10/98	0.74	0.34	0.03	8.9
239	Lift Operator - ML[1]	5/18/98	0.76	0.29	0.03	10
240	Area - Glass Dump - ML[1]	6/10/98	0.82	0.36	0.01	2.8
242	Clean-up - ML[1]	6/10/98	0.85	0.36	0.04	11

[1] ML: Main Line, SL: Spurs Line
[2] Percent-by-weight adipic acid in airborne total dust.

Table 5. Descriptive Statistics for Total Dust and Adipic Acid
HHE 97-0265, AFG Industries, Bridgeport, West Virginia

Substance	Sample Size	Mean (mg/m^3)	SD (mg/m^3)	Range (mg/m^3)
Adipic Acid (Impactor Samples)	6	0.05	0.02	0.02 to 0.08
Total Dust (Impactor Samples)	6	0.66	0.71	0.29 to 2.11
Adipic Acid (Filter Cassette Samples)	15	0.10	0.22	0.01 to 0.89
Total Dust (Filter Cassette Samples)	15	0.50	0.35	0.25 to 1.68

SD - Standard deviation.

Table 6. Adipic Acid Impactor Sampling Results (Cascade Impactor)
HHE 97-0265, AFG Industries, Bridgeport, West Virginia

Sample Number[1]	Job/Area[2]	Sample Date	Volume (m^3)	Total Dust Conc (mg/m^3)	Adipic Acid Conc (mg/m^3)	Adipic Acid Percent Mass[4]
248-1	Packer- ML	6/10/98	0.81	0.19	0.02	48
248-2	Packer- ML	6/10/98	0.81	0.12	0.02	52
248-F	Packer- ML	6/10/98	0.81	0.12	ND[3]	<1
248-Total	Packer- ML			0.43	0.04	–
249-1	Bridge Utility	6/10/98	0.86	0.21	0.04	48
249-2	Bridge Utility	6/10/98	0.86	0.07	0.02	30
249-F	Bridge Utility	6/10/98	0.86	0.11	0.02	22
249-Total	Bridge Utility			0.39	0.08	–
250-1	Packer- ML	6/10/98	0.82	0.11	0.02	52
250-2	Packer- ML	6/10/98	0.82	0.08	0.02	48
250-F	Packer- ML	6/10/98	0.82	0.09	ND[3]	<1
250-Total	Packer- ML			0.28	0.04	–
251-1	Spurs Line	6/10/98	0.75	0.18	0.02	50
251-2	Spurs Line	6/10/98	0.75	0.10	0.02	50
251-F	Spurs Line	6/10/98	0.75	0.14	ND[3]	<1
251-Total	Spurs Line			0.42	0.04	–
255-1	Area- Main Line	5/18/98	0.76	1.81	0.02	100
255-2	Area- Main Line	5/18/98	0.76	0.10	ND[3]	<1
255-F	Area- Main Line	5/18/98	0.76	0.19	ND[3]	<1
255-Total	Area- Main Line			2.10	0.02	–
257-1	Packer- SL	5/18/98	0.81	0.17	0.03	49
257-2	Packer- SL	5/18/98	0.81	0.12	0.03	51
257-F	Packer- SL	5/18/98	0.81	0.01	ND[3]	<1
257-Total	Packer- SL			0.30	0.06	–

[1]Sample number designations 1,2, and F refer to impactor stages with median aerodynamic cut points (in micrometers - μm) of: 1 = 10μm, 2 = 3.5μm, and F = 0.1 μm
[2] ML: Main Line, SL: Spurs Line
[3] Not detectable, limit of detection (LOD) = 5μg /sample
[4]By stage (Total)

Table 7. Percent of symptoms stratified by job category (N=138)
HHE 97-0265, AFG Industries, Bridgeport, West Virginia

Job category	COUGH IN THE MORNING (%)	PHLEGM IN THE MORNING (%)	CHEST TIGHTNESS (%)	WHEEZE (%)
COLD END (N=87)	34 (39)	40 (46)	44 (51)	42 (48)
HOT END (N=14)	9 (64)	10 (71)*	10 (71)	12 (86)†
WAREHOUSE (N=23)	9 (39)	11 (48)	9 (39)	11 (48)
MAINTENANCE (N=14)	6 (43)	4 (29)	9 (64)	6 (43)
TOTAL (N=138)	58 (42)	65 (47)	72 (52)	71 (51)

* p value <0.05, compared to maintenance
† p value <0.05, compared to all categories

Table 8. Percent of symptoms stratified by smoking status (N=138)
HHE 97-0265, AFG Industries, Bridgeport, West Virginia

Smoking status	COUGH IN THE MORNING	PHLEGM IN THE MORNING	CHEST TIGHTNESS	WHEEZE
NEVER (N=59)	14 (24)	21 (36)	29 (50)	26 (44)
CURRENT (N=31)	22 (71)*	22 (71)*	20 (67)	25 (80)*
FORMER (N=48)	20 (42)	21 (44)	22 (46)	20 (43)
TOTAL (N=138)	58 (42)	65 (47)	72 (53)	71 (52)

* p value <0.05, compared to never and former smokers

Table 9. Percent of symptoms stratified by job category and smoking status (N=138)
HHE 97-0265, AFG Industries, Bridgeport, West Virginia

Job category	COUGH IN THE MORNING (%)			PHLEGM IN THE MORNING (%)			CHEST TIGHTNESS (%)			WHEEZE (%)		
	SMOKING STATUS											
	C	F	N	C	F	N	C	F	N	C	F	N
COLD END (N=87)	14 (16)	8 (9)	12 (14)	14 (16)	9 (10)	17 (20)	13 (15)	10 (11)	21 (24)	17 (20)	8 (9)	17 (20)
HOT END (N=14)	4 (29)	5* (36)	0 (0)	4 (29)	5* (36)	1 (7)	4 (29)	4 (29)	2 (14)	5 (36)	5* (36)	2 (14)
WAREHOUSE (N=23)	4 (17)	4 (17)	1 (4)	5 (22)	5 (22)	1 (4)	4 (17)	4 (17)	1 (4)	3 (13)	4 (17)	4 (17)
MAINTENANCE (N=14)	0 (0)	3 (21)	3 (21)	0 (0)	2 (14)	2 (14)	0 (0)	4 (29)	5 (36)	0 (0)	3 (21)	3 (21)
TOTAL (N=138)	22 (16)	20 (14)	16 (12)	23 (16)	21 (15)	21 (15)	21 (15)	22 (16)	29 (21)	25 (18)	20 (14)	26 (19)

C: Current smoker, F: Former smoker, N: Never smoker

* p value <0.05, compared to cold end workers; hot end workers compared to other job categories was not statistically significant different.

Table 10. Percent of symptoms associated to mucosal irritation stratified by job category (N=138)
HHE 97-0265, AFG Industries, Bridgeport, West Virginia

Job category	NASAL BLEEDING	SKIN IRRITATION	EYE IRRITATION
COLD END (N=87)	26 (30)	41 (47)	65 (75)
HOT END (N=13)	3 (23)	9 (69)	9 (69)
WAREHOUSE (N=23)	5 (22)	4 (17)	13 (57)
MAINTENANCE (N=14)	1 (7)	5 (36)	11 (79)
TOTAL (N=138)	35 (25)	59 (43)	98 (71)

Appendix 1
Evaluation Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[2] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[3] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[4] NIOSH encourages employers to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm.[4] Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PEL's and STEL's. An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8-to-10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values (C) which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Occupational exposure criteria for the air contaminants measured during this HHE are provided below as the NIOSH RELs, ACGIH TLVs, and OSHA PELs :

Substance	NIOSH REL	OSHA PEL	ACGIH TLV
Crystalline Silica*	0.05 mg/m^3 - (TWA)	$\frac{10\ mg/m^3}{\%\ SiO_2 + 2}$ - (TWA)	0.1 mg/m^3 - (TWA)
Adipic Acid	None	5 mg/m^3 - (TWA)**	5 mg/m^3 - (TWA)
Sulfur Dioxide	2 ppm - (TWA) 5 ppm - (C)	5 ppm - (TWA)	2 ppm - (TWA) 5 ppm - (STEL)

*Suspected human carcinogen
** As Particulates Not Otherwise Regulated (PNOR). This category is intended for inert or nuisance dusts not listed specifically by substance name, with little potential for induction of inflammation.